Studying the Effects of Land Use on Sediment Loads, Little Missouri National Grasslands, North Dakota

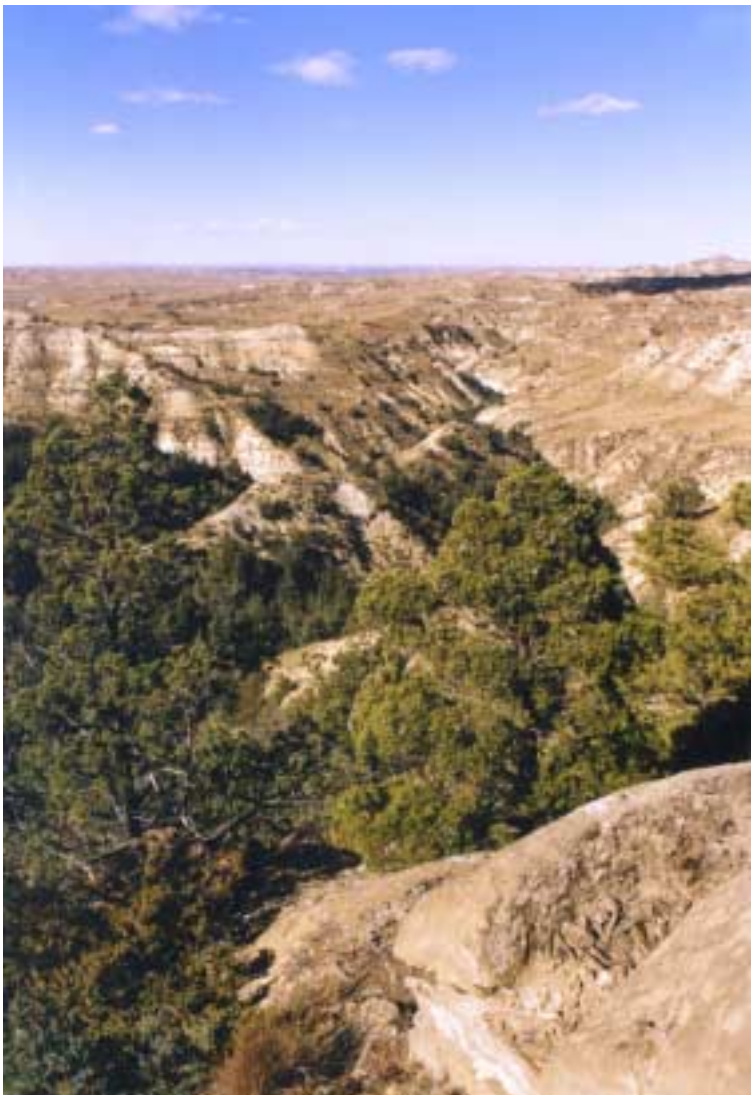
INTRODUCTION

The Little Missouri National Grasslands in North Dakota were established in 1960 and are publicly owned lands administered by the U.S. Department of Agriculture (USDA) Forest Service. The grasslands are not solid blocks of National Forest Systems lands but are lands intermingled with other Federal, State, and privately-owned lands. The mixed-ownership pattern creates a unique environmental management arrangement within each grasslands area.

The USDA Forest Service needs to determine how changes in land use affect loss of sediment from the grasslands, especially during periods of high runoff or after a grassland fire. Excessive sediment loss has the potential to destabilize hillslopes and channels by increasing runoff potential, by prohibiting natural revegetation, by changing animal habitation patterns, and by impacting areas farther downslope and downstream of affected areas.

On October 31, 1999, two major grassland fires occurred in the Little Missouri National Grasslands area. The Squaw Gap Fire affected 51,627 acres and the Rough Creek Fire affected 7,979 acres. Runnoff caused substantial erosion when many road ditches and culverts were filled with sediment and some roads were washed out. In order to implement the best management practices within the Little Missouri National Grasslands, the USDA Forest Service will need sediment information related to land-use changes such as burned and unburned areas and grazed and ungrazed areas.

The Little Missouri National Grasslands are located along the Little Missouri River in western North Dakota (fig. 1). The Grasslands are comprised of 1,028,000 acres predominantly in an area of rolling hills, sparsely covered buttes, coulees, woody draws, and badlands. Most of the area is used as rangeland; but, some of the area is cultivated or used for oil and gas development. The Grasslands have semiarid climate with short, warm summers and long, cold winters. The Grasslands receive an average annual precipitation of about 13 to 15 inches, which generally occurs from April through June. Runoff is produced by snowmelt during the spring or by rainfall over individual watersheds during the warmer months. Temperatures have ranged from about -30 degrees Fahrenheit during the winter to over 100 degrees Fahrenheit during the summer. The average growing season is about 125 days.



The Badlands of the Little Missouri National Grasslands, North Dakota.

PURPOSE AND SCOPE

The information in this report explains the purpose, scope, and approach of the study being conducted in the Little Missouri National Grasslands. The purpose of the study is to determine the sediment loads for different land uses in selected watersheds located within the Little Missouri National Grasslands. Sediment loads will be determined from 43 plots that represent various land uses. Land-use practices for each plot will be controlled as much as possible during the study period. Land uses include natural or ungrazed, continuous grazed, and burned areas. Sediment loads will be determined for each runoff event and each season (snowmelt/spring and rainfall/summer). The plots are located in the northwest portion of the Little Missouri National Grasslands in McKenzie County, N. Dak. (fig. 1). Plans are to collect 5 years of data.

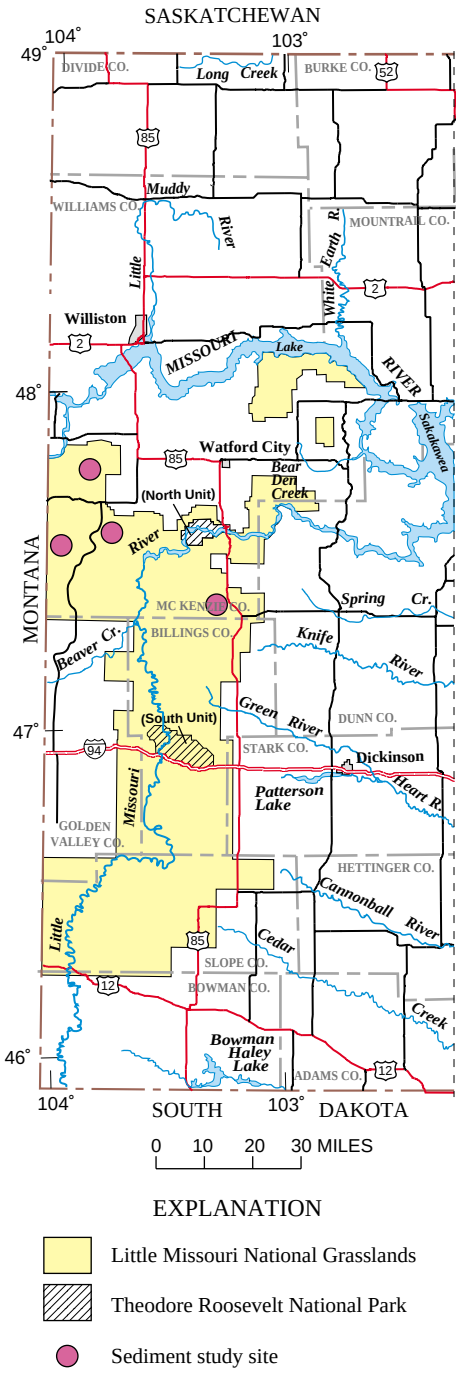


Figure 1. Location of sediment study sites within the McKenzie District of the Little Missouri National Grasslands, North Dakota.

STUDY PLOTS FOR SEDIMENT LOADS

During the initial year of the study (2002), 43 plots were established to measure sediment loads within controlled land-use environments. Of the 43 plots, 36 are located at 3 grasslands sites within the rolling prairie watersheds and 7 are located at 1 woody draw site within the badlands watersheds.

Depending on the plot locations, the plot sizes vary from about 450 square feet to a few acres. Plot locations were determined on the basis of terrain type and land use. Actual plot locations and dimensions were determined from subsequent site inspections and from the help of USDA Forest Service personnel. The number and distribution of plots may be altered after the initial field season to refine data collection.

Each of the three grasslands sites within the rolling prairie watersheds has a different slope but a similar soil type and aspect. At each site, four natural or ungrazed plots, four continuously grazed plots, and four burned plots were established. Some of the plots were fenced to protect the land-use environment from cattle or other grazing domestic animals.

Plot sizes for the grasslands sites are at least 450 square feet or 15 feet wide and 30 feet long. A minimum plot size is needed to account for rill development or other small-scale erosional features that can be critical factors in sediment movement. The plots do not contain any major breaks in topography. The upper-slope boundary of the plots are partially or wholly edged to define a mutually exclusive contributing area. The downslope boundary of the plots consists of a sediment fence placed perpendicular to the runoff flow.

At the Badlands site, six of the plots were placed in groups of three on two opposite-facing slopes of the woody draw as far upslope in the watershed as possible. The seventh plot was placed across the mainstem of the woody draw site downslope of the other six plots. Sediment fences were installed at each plot and a secondary backup sediment fence was placed just downslope of the mainstem of the woody draw sediment fence.

A Belfort Universal rain gage was placed at each grasslands site, and a tipping bucket rain gage was placed at each grasslands site and at the woody draw site. The orifices for all of the rain gages are at the same height from ground level. Data from the rain gages are recorded by a data logger and by a storage module that are enclosed in a weatherproof housing unit. To minimize the effects of horizontal wind-related errors, an Alter-type windshield was placed around each Belfort Universal rain gage.

Wind speed and wind direction are being collected. Wind speed and wind direction sensors were placed near the rain gages at the same height as the rain gage orifices. Wind data are recorded by the data logger.

At each site, soil moisture probes were placed horizontally within the first foot of soil to measure the amount of moisture that penetrates the soil during a rainstorm event. Soil moisture data also are recorded by the data logger.

PROCESS OF DATA COLLECTION

Plans are to visit the plots after each rainstorm event. However, if more than one rainstorm event occurs between visits, sediment samples will be collected for the combined rainstorm events. During each visit, the sediment collected by the sediment fence will be collected, weighed, and recorded. Before the sample is weighed, any organic debris larger than several inches or any rocks of substantial weight will be

USDA Forest Service personnel monitoring a prescribed burn on a set of grasslands plots.

U.S. Geological Survey personnel collecting data at a grasslands site near Sheep Butte, North Dakota.

removed from the sample. A description of the debris will be recorded. Sediment samples will be delivered to a laboratory for particle size and organic composition analyses. Soil from the sediment fence will be discarded downslope of the fence.

Before snowmelt, snow depth and density surveys will be completed at each plot. The surveys will be completed near the peak snow accumulation at each site and will provide an estimation of the amount of snow-water equivalent available for runoff.

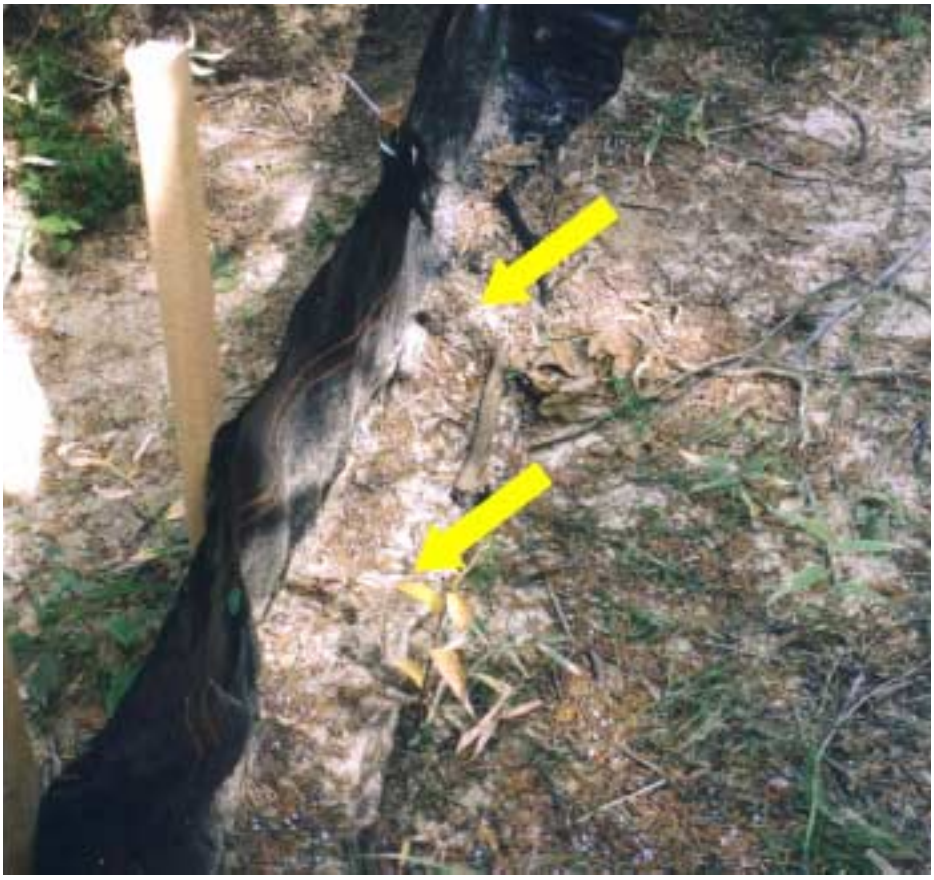
Soils and vegetative cover are important factors used to determine the amount of sediment loss in an area. Soil types will be determined by the samples collected at each plot. Depending on the growing season and on the current land use, the amount and types of vegetative cover may need to be assessed several times each year at every plot. Changes in land-use patterns also will be noted and recorded for each plot. Periodically, photographs of each plot will be taken from established viewpoints to record any visual changes in vegetation and land surfaces. Geomorphic attributes for each site will be noted.

DATA ANALYSIS

The statistical approach that is planned to be used for the grasslands sites is different than the approach that is planned to be used for the woody draw site. At the grasslands sites, rather than using a nonlinear regression model to explain variation in sediment loads among the various plots, the variation will be controlled as much as possible so direct comparisons can be made among loads for different land uses. Plots will be selected that are in close proximity to one another and that are expected to have similar rainstorm events. Land-use types that are being used for the grasslands sites are natural or ungrazed, continuously grazed, and burned. Within each land-use type, four plots were established with sediment fences. Whenever possible, the four plots within each land-use type were selected to represent the same slope. Sediment loads will be calculated for each season and, whenever possible, for individual rainstorm events. Analysis of variance will be used to determine whether there are statistically significant differences among the land-use types.

At the woody draw site, data from the sediment fences will be used to calculate sediment loads for each plot and for each snowmelt/spring and rainfall/summer season. Whenever possible, sediment loads also will be calculated for individual runoff events. Sediment loads for individual runoff events will be modeled by using a nonlinear regression model to predict loads on the basis of explanatory variables such as rainfall intensity, slope, vegetative cover, and other site-specific variables. Hillslope erosion models will be used to determine appropriate equations to relate loads to the explanatory variables. The nonlinear regression model that is used to predict loads at individual plots and to predict individual runoff events will be used to estimate the total loads for each snowmelt/spring and rainfall/summer season. For each season, the estimated loads from the nonlinear regression model will be compared to the calculated loads that were obtained

Instrumentation and sediment fences at the badlands site.



Sediment and organic debris collected by a sediment fence.

from the sediment data. The comparison will determine how well the regression model will estimate total loads for an extended time period.

The nonlinear regression model will be used to estimate total loads for small watersheds. Data collected at the sediment fence across the mainstem of the small watershed will be used to calculate total loads for the watershed for each season and, whenever possible, for individual runoff events. The estimated loads for the regression model will be compared to the calculated loads for the watershed to determine how well the regression model estimates total loads for small watersheds.

Comparisons will be made among sediment loads for different land uses and statistical analyses will be used to determine whether sediment loads depend on land use. A nonlinear regression model that predicts sediment loads will be calibrated for plots that are natural, grazed, and burned. The outcome of the statistical analyses for land-use comparisons will depend on the ability of the nonlinear regression model to predict sediment loads for the various seasons and for small watersheds. If the regression model can explain variation in loads because of rainfall, slope, vegetative cover, and other explanatory variables, then the standard error of the regression model will be small and the residuals from the regression model can be compared among land-use types to determine whether there are any differences because of land use. However, if the standard error of the regression model is large, unexplained variation in the sediment loads may be too large to detect the differences because of land-use type (unless the differences are so large that they can be detected even with high variation in the noise).

—K.M. Macek-Rowland

For additional information on the U.S. Geological Survey, North Dakota District and the U.S. Department of Agriculture Forest Service National Grasslands, contact the following Internet sites:

USGS, North Dakota District	http://nd.water.usgs.gov/
USDA Forest Service	http://fs.fed.us/grasslands
Dakota Prairie Grasslands	http://www.fs.fed.us/r1/dakotaprairie

For more information contact any of the following:

For North Dakota District USGS information:
District Chief
821 East Interstate Avenue
Bismarck, ND 58503-1199
(701) 250-7401

For more information on all USGS reports and products (including maps, images, and computerized data), call 1-800-USA-MAPS.

Additional earth science information can be found by accessing the USGS "Home Page" on the World Wide Web at "http://www.usgs.gov".

U.S. Department of the Interior
U.S. Geological Survey
Open-File Report 02-427
2002